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(Diacetoxyiodo)benzene mediated metal-free C(sp^2)-H phenylselenation of imidazo[1,2-*a*]pyridines and imidazo[2,1-*b*]thiazoles using diphenyl diselenide

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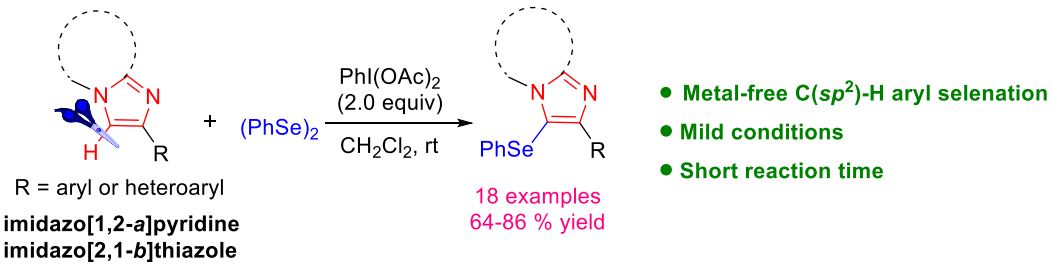
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Abstract

Metal-free (diacetoxy)iodobenzene-mediated C(sp^2)-H phenylselenation of imidazo[1,2-*a*]pyridines and imidazo[2,1-*b*]thiazoles using diphenyl diselenide has been developed. This protocol exhibits broad substrate scope with good to excellent yields of the phenyl selenation product of imidazoheterocycles under mild conditions in short reaction times.



Keywords: Imidazo[1,2-a]pyridines, diphenyl diselenide, hypervalent iodine, selenation, metal-free oxidation

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Introduction

The organoselenium compounds are important building blocks in organic synthesis.[1] The derivatives of organoselenium compounds also have applications in material sciences as fluorescent probes.[2] Moreover, the organoselenium compounds and their subsequent investigations for biological activity have attracted a considerable attention from organic and medicinal chemists over the past few years.[3] A number of unsymmetrical aryl-Se-heteroaryl compounds show various pharmacological properties such as antitumor,[4] anti-oxidant,[5] anti-proliferative,[6] antimicrobial[7] and anticholinesterase activities.[8] Therefore, a wide range of synthetic methodologies have been developed for arylselenation of a plethora of heterocycles such as thiophenes, chromones, arenofurans, quinolone, purine, indole, benzothiazoles, antipyrine and imidazo[1,2-*a*] pyridines.[9]

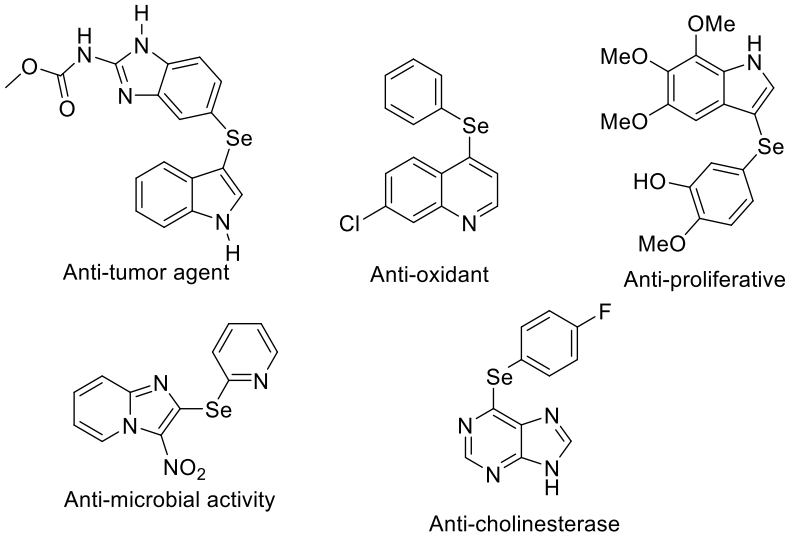
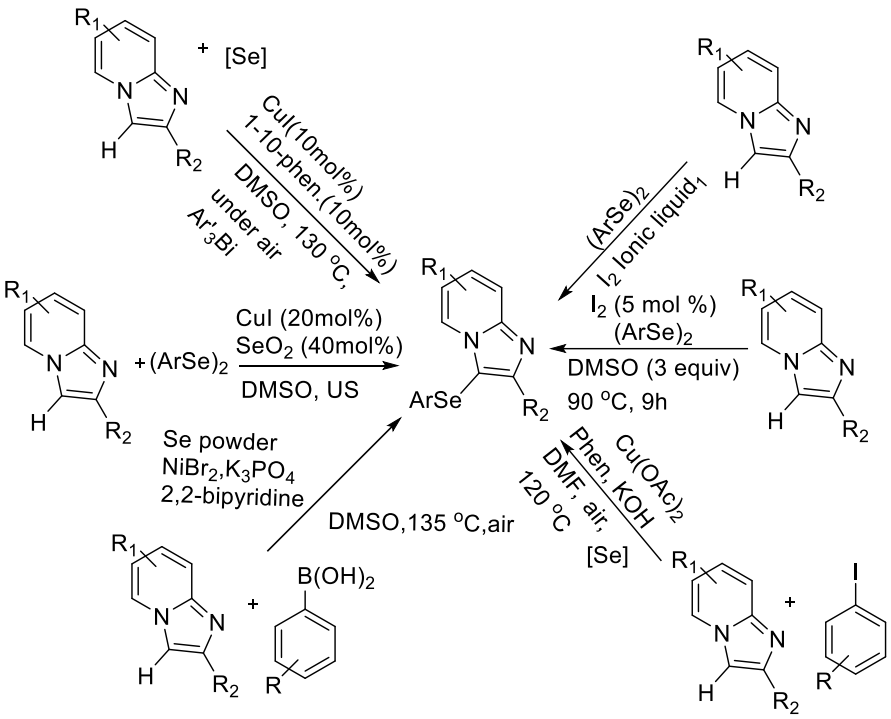


Figure 1. Examples of biologically active heteroarylselenides

On the other hand, the imidazo[1,2-*a*] pyridine heterocyclic scaffold exhibits significant therapeutic properties such as cytotoxic, antitumor, antiprotozoal, antiviral, antimicrobial, antiherpes, anticancer, and anticonvulsant activities.[10] In addition, imidazo[1,2-*a*] pyridine sub-structural unit is also found in many commercial drugs such as Alpidem, Miroprofen, Zolimidine and olprinone.[11] The properties of imidazo[1,2-*a*] pyridines mainly depends on substituent at C3-position and therefore, a wide range of methodologies have been developed for C3 alkylation, arylation, carbonylation, thiolation, sulfenylation, selenation, halogenation and phosphyrylation reaction.[12] Owing to the importance of organoselenium compounds, the synthesis of 3-arylselenylimidazo[1,2-*a*]pyridines has gained much attention in recent years (Scheme 1). The methods for the phenylselenylation of imidazo[1,2-*a*]pyridines at C3-position include: (i) electrophilic substitution employing phenylselenium bromide,[13] (ii) oxidative phenylselenation with diphenyl diselenide using CuI,[14-15] I_2 in DMSO or ionic liquid,[16-17] KIO_3,[18] oxone[19] (iii) transition metal-catalysed cross-coupling reactions of selenium powder with iodoarenes or arylboronic acid or 4-coumarinyl triflates,[20-23] (iv) visible-light driven aerobic oxidation using diphenyl diselenide.[24] Recently, phenylselenation of coumarins and other heteroarenes has been reported by Guang Liang et. al. using (bis(trifluoroacetoxy)iodo)benzene.[25] Some of the above reported methods for the the arylselenylation of imidazo[1,2-*a*]pyridines are associated with certain drawbacks such as limited substrate scope, expensive metal catalysts, harsh conditions, requirement of additives or ligands, long reaction time and prefunctionalization of commercial substrates. Therefore, it is desirable to develop a new mild method for the the arylselenylation of imidazo[1,2-

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a]pyridines derivatives. In continuation of our work on hypervalent iodine reagents,[26-27] herein, we report a metal-free direct phenylselenation of imidazo[1,2-*a*]pyridines and imidazo[2,1-*b*]thiazoles with diphenyl diselenide using (diacetoxyiodo)benzene (DIB) as an oxidant under mild conditions (Scheme 2).



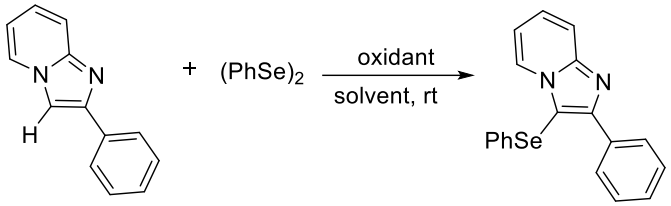
Scheme 1. Literature methods for phenylselenation of imidazo[1,2-*a*]pyridines

Results and Discussion

Trivalent iodine reagent, DIB was selected as an oxidant for carrying out the reaction between 2-phenylimidazo[1,2-*a*]pyridine **1a** and diphenyl diselenide in the model experiment. The optimization reactions were carried out using different stoichiometric combinations of DIB as well as screening of solvents to improve the yield of the product (Table 1). The initial attempts to employ CH_2Cl_2 as solvent resulted in poor yield of **2a** at room temperature (entry 1). When CH_3CN was used as solvent, the situation was the same (entry 2). An effort was made to increase the yield of the reaction by increasing the temperature but results weren't as expected (entries 3-4). However, to our surprise, the product yields were improved significantly by increasing the quantity of DIB as well as using CH_2Cl_2 and CH_3CN as solvent system (entries 5-6) and bringing down the reaction time to one hour. The maximum yield 86% of **2a** was achieved using 2.0 equivalents of DIB in CH_2Cl_2 solvent system (entry 5). Other solvents such as MeOH was found to be unsatisfactory for the formation of **2a** in good yields (entries 7-8). When other hypervalent iodine reagents such as bis(trifluoroacetoxyiodo)benzene or [(hydroxy)tosyloxyiodo]benzene were used, poor yields were obtained (entries 9-10). The *in situ* generated hypervalent iodine(III) reagent from the reaction of catalytic iodobenzene with MCPBA as oxidant was also examined for the reaction (entries 11-12). However, in these cases, we couldn't get corresponding **2a** in satisfactory yields. Thus, the optimum reaction condition was accomplished by using imidazo[1,2-*a*]pyridine **(**1 equiv), diphenyl diselenide (1 equiv) and DIB (2 equiv) in CH_2Cl_2 as solvent for getting maximum yield of phenylselanyl imidazole[1,2-*a*]pyridine **2a** (entry 5).

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Table 1. Screening of reaction conditions



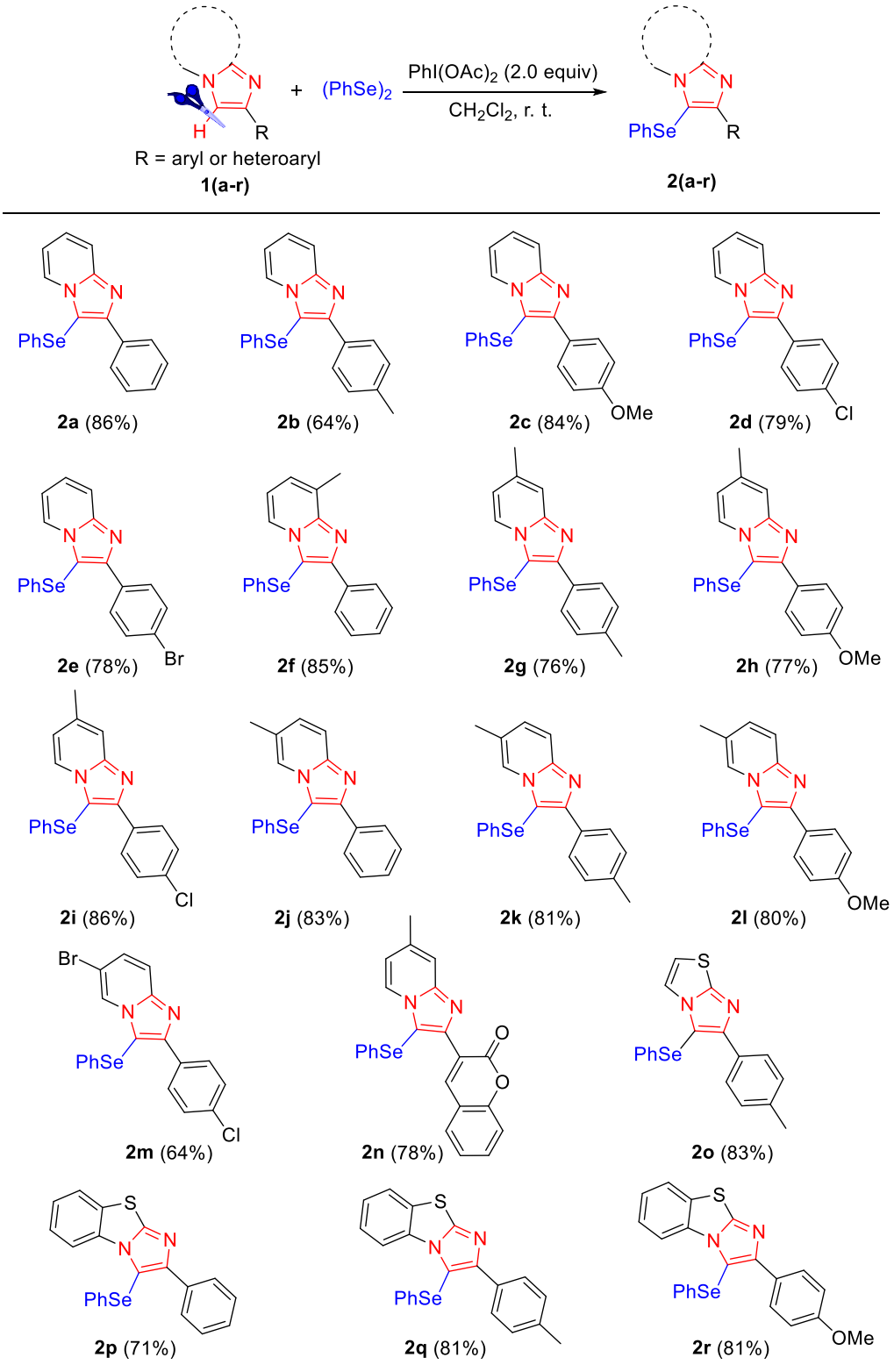
1a **2a**

Entry	Oxidants and conditions	Solvent	Time (h)	Yield[a] (%)
1	$PhI(OAc)_2$ (1.25 equiv)	CH_2Cl_2	24	20
2	$PhI(OAc)_2$ (1.25 equiv)	CH_3CN	24	34
3	$PhI(OAc)_2$ (1.5 equiv) reflux at 50 °C	CH_2Cl_2	02	42
4	$PhI(OAc)_2$ (1.5 equiv) reflux at 50 °C	CH_3CN	02	44
5	**$PhI(OAc)_2$ (2.0 equiv)**	**CH_2Cl_2**	**01**	**86**
6	$PhI(OAc)_2$ (2.0 equiv)	CH_3CN	01	40
7	$PhI(OAc)_2$ (1.5 equiv)	CH_3OH	24	10
8	$PhI(OAc)_2$ (1.5 equiv)	CH_3OH	01	18
9	PhI(OH)(OTS) (1.5 equiv)	CH_2Cl_2	24	12
10	$PhI(OCOCF_3)_2$ (1.5 equiv)	CH_2Cl_2	24	15
11	PhI (0.1 equiv), MCPBA (1.5 equiv)	CH_3CN	24	13
12	PhI (0.5 equiv), MCPBA (1.5 equiv)	CH_3CN	24	17

[a]All listed yields are isolated ones.

With the optimized reaction conditions, we explored the substrate scope of the present protocol, as shown in Scheme 2. This methodology works with a variety of imidazo[1,2,*a*]pyridines bearing electron-donating and withdrawing groups either at aryl or pyridine moieties (**2a**-**2m**). The yield of the reactions doesn't vary with electronic effect of the substituents proportionally. The steric hindrance also did not have much effect and imidazo[1,2,*a*]pyridines having methyl groups at different positions reacted efficiently with DIB and diphenyl diselenide to form the respective phenylselanyl imidazole[1,2-*a*]pyridine**s** in good yields. Coumarin-substituted imidazole[1,2-*a*]pyridine was also effective for such transformation to afford the desired phenylselenation product in good yield (**2n**). To extend the generality of this methodology, we investigated the phenylselenation reaction with related heterocycle such as imidazo[2,1-b]thiazole. Thus, 6-(*p*-tolyl)imidazo[2,1-*b*]thiazole reacted well to afford the desired 5-(phenylselanyl)-6-(*p*-tolyl)imidazo[2,1-*b*]thiazole (**2o**) in satisfactory yields. Similarly, 2-arylbenzo[*d*]imidazo[2,1-*b*]thiazole containing electron-donating groups such as methyl and methoxy substituents underwent the phenylselenation reaction without any difficulties (**2p**-**2r**).

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[a]Reaction conditions: **1** (1 mmol), $(PhSe)_2$ (1 mmol) and DIB (2 mmol) in CH_2Cl_2 at rt stirring. Yields are of isolated pure products.

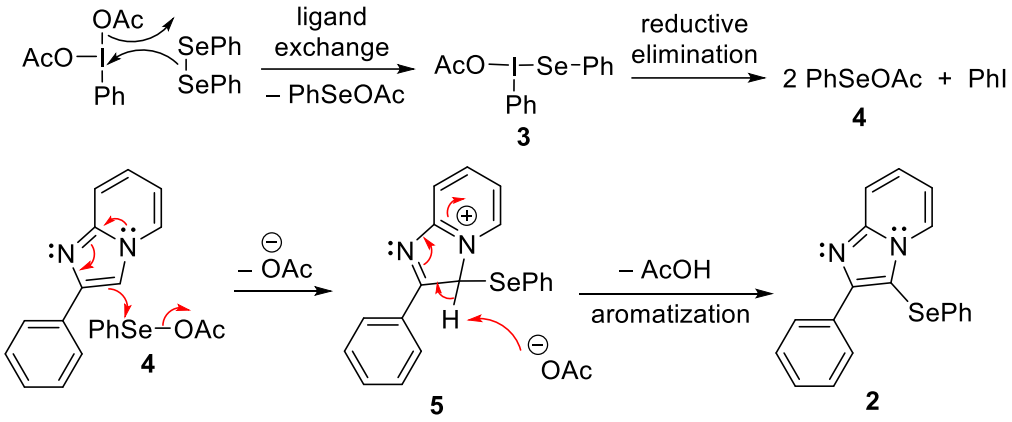
Scheme 2. Phenylselenation of imidazoheterocycles using diphenyl diselenide and DIB[a]

Mechanism

A plausible mechanism for phenylselenation of imidazo[1,2-α]pyridines with 1,2-diphenyldiselane using DIB is shown in scheme 3. The ligand exchange reaction between DIB and PhSeSePh can generate a putative intermediate PhI(OAc)SePh **3**. The propensity of intermediate **3** for reductive elimination of

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iodobenzene may generate electrophilic benzeneselenenyl acetate **4**.[28] The imidazo[1,2-*a*]pyridines **1** attacks on electrophilic benzeneselenenyl acetate **4** through its C3 position to form σ-complex **5** which undergoes aromatization to furnish 3-phenylseleno imidazo[1,2-*a*]pyridines **2**. However, the possibility of free radical mechanism for phenylselenation of imidazo[1,2-*a*]pyridines using DIB and PhSeSePh cannot be ruled out.[25]



Scheme 3. Plausible mechanism for the phenylselenation of imidazo[1,2-α]pyridines with 1,2-diphenyldiselane using DIB

Conclusions

In summary, we have developed an efficient and operationally simple protocol for the direct phenylselenation of imidazo[1,2-*a*]pyridines and imidazo[2,1-*b*]thiazoles with diphenyl diselenide using DIB as trivalent iodine oxidizing agent. This method features transition-metal-free oxidation under mild reaction conditions, a wide substrate scope, and good to excellent yields, thus paving an efficient and useful way to establish a library of potentially biologically active molecules.

Experimental Section

General procedure for phenylselenation of imidazoheterocycles: To a stirred solution of diphenyl diselenide (1 mmol) in CH_2Cl_2 (5 mL), diacetoxyiodobenzene (2.0 mmol) and imidazo[1,2-a]pyridine or imidazo[2,1-*b*]thiazoles **1** (1 mmol) were sequentially added into a 50 mL round bottom flask. The reaction mixture was stirred at room temperature for 1 h. The progress of the reaction was monitored by TLC. After completion, water was added to cease the reaction and the aqueous phase was extracted with CH_2Cl_2. The combined organic extracts were dried over Na_2SO_4, filtered, and concentrated under reduced pressure to afford the crude residue. The crude product was purified by column chromatography using petroleum ether (40-60 °C) and ethyl acetate to afford corresponding phenylselenation products of imidazoheterocycles **2** in good to excellent yields.

2-Phenyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2a). Brown solid (198.8 mg, 79% yield); mp 83-85 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 6.90 (td, *J* 6.8, 0.9 Hz, 1H, ArH), 7.10-7.11 (m , 2H, ArH), 7.16-7.19 (m, 3H, ArH), 7.33-7.40 (m, 2H, ArH), 7.44-7.46 (m, 2H, ArH) 7.79 (d, *J* 8.9 Hz, 1H, ArH). 8.15 (dd, *J* 5.2, 1.9 Hz, 2H, ArH). 8.37 (d, *J* 6.8 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 102.8, 113.0, 117.5, 125.6, 126.4,

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126.7, 128.2, 128.3, 128.4, 128.7, 129.7, 130.9, 133.8, 147.7, 151.8; IR (cm^{-1}): 1644, 1466; LCMS (ESI): Calculated for $C_{19}H_{14}N_2Se$ $[M]^+$ 350.03, found $[M+1]^+$ 351.04

3-(Phenylselanyl)-2-(*p*-tolyl)imidazo[1,2-*a*]pyridine (2b). Yellow solid (198.7 mg, 64% yield), mp: 108-110 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.38 (s, 3H, CH_3), 6.85 (td, *J* 6.8, 1.1 Hz, 1H, ArH), 7.09-7.11 (m, 2H, ArH), 7.15-7.18 (m, 3H, ArH), 7.24(s, 2H, ArH), 7.25-7.31 (m, 1H, ArH), 7.72 (dd, *J* 8.9, 2.1 Hz, 1H, ArH), 8.06 (dd, *J* 8.3 , 1.7 Hz, 2H, ArH), 8.34 (dd, *J* 6.8, 2.3 Hz , 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 21.3, 102.5, 112.9, 117.3, 125.5, 126.4, 126.6, 128.8, 128.3, 129.0, 129.6, 130.8, 130.9, 138.3, 147.6, 151.8; IR (cm^{-1}): 1468, 1340; LCMS (ESI):Calculated for $C_{20}H_{16}N_2Se$ $[M]^+$ 364.04, found $[M+1]^+$ 365.05

2-(4-Methoxyphenyl)-3-(phenylselanyl)imidazo[1,2-*a*]pyridine) (2c). Brown solid (186.2 mg, 84% yield), mp 101-105 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 3.84 (s, 3H, OCH_3), 6.85 (td, *J* 6.8, 1.0 Hz, 1H, ArH), 6.98 (dd, *J* 6.8, 2.1 Hz, 2H, ArH), 7.09-7.11 (m, 2H, ArH), 7.15-7.18 (m, 3H, ArH), 7.28-7.31 (m, 1H, ArH) 7.70 (d, *J* 9.3 Hz, 1H, ArH), 8.13 (dd, *J* 9.7, 2.1 Hz, 2H, ArH), 8.34 (dd, *J* 5.9, 0.9 Hz, 1H ArH); ^{13}C NMR (125MHz, *C*DCl_3) (ppm) 55.3, 101.9, 112.8, 113.7, 117.2, 125.5, 126.3, 126.4, 126.6, 128.1, 129.6, 130.0, 131.0, 147.6, 151.6, 159.9; IR (cm^{-1}); 1610, 1467, 1248; LCMS (ESI):Calculated for $C_{20}H_{16}N_2OSe$ $[M]^+$ 380.04, found $[M+1]^+$ 381.05.

2-(4-Chlorophenyl)-3-(phenylselanyl)imidazo[1,2-*a*]pyridine) (2d). White solid (198.4 mg, 79% yield), mp 103-105 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 6.87(td, *J* 6.8, 1.0 Hz, 1H, ArH), 7.07-7.09 (m, 2H, ArH), 7.16-7.18 (m, 3H, ArH), 7.30-7.33 (m ,1H, ArH) 7.41 (dd, *J* 9.1, 2.4 Hz, 2H, ArH), 7.11 (d, *J* 9.0 Hz, 1H, ArH), 8.13 (dd, *J* 9.1, 4.4 Hz, 2H, ArH), 8.35 (dd, *J* 6.8, 0.9 Hz, 1H, ArH) ; ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 103.6, 113.2, 117.5, 125.6, 126.7, 126.8, 128.2, 128.5, 129.7, 129.6, 130.6, 132.2, 134,5, 147.7, 150.5; IR (cm^{-1}): 1644, 1466; LCMS (ESI):Calculated for $C_{19}H_{13}ClN_2Se$ $[M]^+$ 383.99, found $[M+1]^+$ 384.04.

2-(4-Bromophenyl)-3-(phenylselanyl)imidazo[1,2-*a*]pyridine) (2e). White solid (196.5 mg, 78% yield), mp 116-120 ^oC, ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 6.91 (td, *J* 6.8, 1.1 Hz, 1H, ArH), 7.05-7.10 (m, 2H, ArH), 7.17-7.20 (m, 3H, ArH) 7.34-7.37 (m, 1H, ArH), 7.58 (dd, *J* 6.7, 4.4 Hz, 2H, ArH), 7.76 (d, *J* 9.0 Hz, 1H, ArH), 8.07 (dd, *J* 9.1, 4.4 Hz, 2H, ArH), 8.38 (dd, *J* 6.8, 2.1 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm): 103.0, 113.2, 117.5, 112.8, 125.6, 126.7, 126.8, 128.2, 129.7, 130.2, 130.6, 131.4, 132.7, 147.7, 150.5; IR (cm^{-1}): 1643, 1470; LCMS (ESI):Calculated for $C_{19}H_{13}BrN_2Se$ $[M]^+$ 427.94, found $[M+2]^+$ 429.85.

8-Methyl-2-phenyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2f). Yellow solid (258.3 mg, 85% yield); mp 121-125 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.71 (s, 3H, CH_3), 6.77 (t, *J* 6.8 Hz ,1H, ArH), 7.08-7.10 (m, 3H, ArH), 7.14-7.19 (m, 3H, ArH), 7.34-7.37 (m, 1H, ArH), 7.44 (td, *J* 5.6, 2.3 Hz, 2H, ArH), 8.12 (dd, *J* 6.1, 2.0 Hz, 2H, ArH), 8.13 (d, *J* 1.4 Hz, 1H, ArH) ; ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 16.8. 103.1, 112.9, 123.4, 125.1, 126.5, 127.5, 128.2, 128.2, 128.9, 129.6, 131.1, 134.0, 148.0, 151.4; IR (cm^{-1}): 1475, 1346; LCMS (ESI):Calculated for $C_{20}H_{16}N_2Se$ $[M]^+$ 364.04, found $[M+1]^+$ 365.05

7-Methyl-3-(phenylselanyl)-2-(*p*-tolyl)imidazo[1,2-*a*]pyridine (2g). White solid (200.3 mg, 76% yield), mp 108-110 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.37 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 6.66 (dd, *J* 6.9, 1.5 Hz, 1H, ArH), 7.07-7.09 (m, 2H, ArH), 7.13-7.17 (m, 2H, ArH), 7.22-7.25 (m, 3H, ArH), 7.45 (s, 1H, ArH), 8.03 (d, *J* 8.1 Hz, 2H, ArH), 8.19 (d, *J* 6.9 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 21.3, 101.6, 115.5, 115.9, 124.7, 126.5, 128.1, 128.5, 129.0, 129.6, 131.0, 131.3, 137.5, 138.2, 148.0, 151.7; IR (cm^{-1}): 1644, 1471; LCMS (ESI):Calculated for $C_{21}H_{18}N_2Se$ $[M]^+$ 378.06, found $[M+1]^+$ 379.07.

2-(4-Methoxyphenyl)-7-methyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2h). White solid (228.3 mg, 77% yield); mp 108-110 ^oC; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.42 (s, 3H, CH_3), 3.83 (s, 3H, OCH_3) 6.67 (dd, *J* 6.9, 1.6 Hz, 1H, ArH), 6.96 (dd, *J* 6.7, 2.1 Hz, 2H, ArH), 7.08-7.10 (m, 2H, ArH), 7.14-7.17 (m, 3H, ArH), 7.45 (d, *J* 1.3, 1H, ArH), 8.10 (dd, *J* 6.8, 2.1 Hz, 2H, ArH), 8.19 (d, *J* 7.0 Hz, 1H, ArH) ; ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 21.3, 55.2, 101.1, 113.7, 115.4, 115.8, 124.6, 126.4, 126.5,128.0, 129.6, 129.9, 131.3, 137.5, 148.0, 151.5, 159.8; IR (cm^{-1}):1611, 1467; LCMS (ESI):Calculated for $C_{21}H_{18}N_2OSe$ $[M]^+$ 394.05 , found $[M+1]^+$ 395.05

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2-(4-Chlorophenyl)-7-methyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2i). White solid (248.3 mg, 86% yield), mp 103-107 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.43 (s, 3H, CH_3), 6.69 (dd, *J* 7.0, 1.6 Hz, 1H, ArH), 7.06-7.08 (m, 2H, ArH), 7.15-7.18 (m, 3H, ArH), 7.40 (dd, *J* 9.2, 4.5 Hz, 2H, ArH), 7.45 (s, 1H, ArH); 8.11 (td, *J* 9.2, 4.5 Hz, 2H, ArH) 8.21 (d, *J* 7.0 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 21.3, 102.1, 115.8, 116.0, 124.7, 126.7, 128.1, 128.4, 129.7, 129.8, 130.9, 132.3, 134.3, 137.9, 148.0, 150.3; IR (cm^{-1}):1645, 1467; LCMS (ESI):Calculated for $C_{20}H_{15}ClN_2Se$ $[M]^+$ 398.00, found $[M+1]^+$ 399.07.

6-Methyl-2-phenyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2j). White solid (234.3 mg, 83% yield), mp 103-106 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.31 (s, 3H, CH_3), 7.11 (dd, *J* 7.8, 1.6 Hz, 2H, ArH), 7.15-7.20 (m, 4H, ArH), 7.37 (d, *J* 7.3, 1H, ArH), 7.43 (td, *J* 7.8, 1.5 Hz, 2H, ArH), 7.63 (d, *J* 9.1 Hz, 1H, ArH) 8.11-8.14 (m, 3H, ArH); ^{13}C NMR (125MHz, *C*DCl_3) δ (ppm) 18.4, 102.31, 116.8, 112.8, 123.3, 126.5, 128.0, 128.3, 128.6, 129.6, 131.3, 133.9, 146.8, 151.6; IR (cm^{-1}): 1467, 1335; LCMS (ESI): Calculated for $C_{20}H_{16}N_2Se$ $[M]^+$ 364.05, found $[M+1]^+$ 365.05

6-Methyl-3-(phenylselanyl)-2-(*p*-tolyl)imidazo[1,2-*a*]pyridine (2k). White solid (212.3 mg, 81% yield); mp 103-105 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.31 (s, 3H, CH_3), 2.38 (s, CH_3, 3H), 7.09-7.11 (m, 2H, ArH), 7.14-7.18 (m, 4H, ArH), 7.24 (d, *J* 7.1 Hz, 2H, ArH), 7.62 (d, *J* 9.0 Hz, 1H, ArH), 8.03 (d, *J* 8.1 Hz, 2H, ArH), 8.13 (s, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 18.3, 21.3, 102.0, 116.7, 122.6, 123.3, 126.5, 128.0, 128.5. 129.0, 129.4, 129.6, 131.0, 131.3, 138.1, 146.7, 151.7; IR (cm^{-1}): 1466, 1334; LCMS (ESI): Calculated for $C_{21}H_{18}N_2Se$ $[M]^+$ 378.06, found $[M+1]^+$ 379.07

2-(4-Methoxyphenyl)-6-methyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2l). White solid (189.7 mg, 80% yield), mp 103-108 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.29 (s, 3H, CH_3), 3.81 (s, 3H, OCH_3), 6.96 (dd, *J* 6.8, 2.9 Hz, 2H, ArH) , 7.08-7.11 (m, 2H, ArH) 7.11-7.18(m, 4H, ArH), 7.59 (d, *J* 9.2Hz, 1H, ArH), 8.11 (dd, *J* 9.7, 2.9, 2H ArH), 8.12 (s, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 18.3, 55.2, 101.4, 113.7, 116.3, 122.6, 123.2, 126.5, 128.0, 129.4, 129.6, 129.8, 131.4, 146.7, 151.5, 159.8; IR (cm^{-1}): 1465, 1243 LCMS (ESI):Calculated for $C_{21}H_{18}N_2OSe$ $[M]^+$ 394.05, found $[M+1]^+$ 395.09.

6-Bromo-2-(4-chlorophenyl)-3-(phenylselanyl)imidazo[1,2-*a*]pyridine (2m). White solid (198.7 mg, 64% yield), mp 121-123 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 7.08-7.10 (m, 2H, ArH), 7.20-7.21 (m, 3H, ArH *)*, 7.37-7.41 (m, 3H, ArH), 7.61 (d, *J* 9.4 Hz, 1H, ArH), 8.11 (dd, *J* 6.2, 1.9 Hz, 2H, ArH), 8.51 (d, *J* 1.1 Hz, 1H); ^{13}C NMR (125 MHz,*C*DCl_3) δ(ppm) 103.6, 108.1, 118.1, 125.8, 127.1, 128.3, 128.6, 129.9, 129.9, 130.1, 130.2, 131.7, 134.7, 146.1, 151.0; IR (cm^{-1}): 1476, 1326; LCMS (ESI):Calculated for $C_{19}H_{12}BrClN_2Se$ $[M]^+$ 461.90, found $[M+2]^+$ 463.83.

3-(7-Methyl-3-(phenylselanyl)imidazo[1,2-*a*]pyridin-2-yl)-2H-chromen-2-one (2n). White solid (199.4 mg, 78%), mp 109-112 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.43 (s, 3H, CH_3), 6.70 (dd, *J* 7.0, 1.3 Hz, 1H, ArH), 7.08-7.10 (m, 2H, ArH), 7.14-7.17 (m, 3H, ArH), 7.28-7.29 (m, 1H, ArH), 7.30 (d, *J* 8.2 Hz, 1H, ArH) 7.49-7.55 (m, 3H, ArH), 8.08 (s, 1H, ArH), 8.11 (d, *J* 6.9 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) *δ* (ppm) 21.4, 106.2, 116.2, 116.2, 116.7, 119.3, 122.4, 124.5, 124.8, 126.8, 127.4, 128.3, 129.0, 129.6, 130.7, 132.0, 137.9, 143.5, 146.3, 147.9, 154.1 ,160.1; IR (cm^{-1}): 1258, 1018; LCMS (ESI):Calculated for $C_{23}H_{16}N_2O_2Se$ $[M]^+$ 431.03, found $[M+1]^+$ 432.12.

5-(Phenylselanyl)-6-(*p*-tolyl)imidazo[2,1-*b*]thiazole) (2o). White solid (201.5 mg, 83% yield), mp 120-123 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.26 (s, 3H, CH_3), 6.67 (d, *J* 4.5, 1H, ArH), 7.05-7.10 (m, 5H, ArH), 7.15 (m, 2H, ArH), 7.30 (d, *J* 4.5 Hz, 1H, ArH), 7.89 (d, *J* 8.2, 2H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm**)** 21.2, 101.9, 112.2, 118.6, 126.5, 127.5, 128.3, 128.9, 129.5, 130.9, 131.4, 137.7, 151.3, 152.9; IR (cm^{-1}): 1260, 1026; LCMS (ESI): Calculated for $C_{18}H_{14}N_2SSe$ $[M]^+$ 370.00, found $[M+1]^+$ 371.04.

2-Phenyl-3-(phenylselanyl)benzo[*d*]imidazo[2,1-*b*]thiazole) (2p). Brown solid (226.2 mg, 71% yield), mp 121-124 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ (ppm) 7.15-7.17 (m, 1H, ArH), 7.21-7.26 (m, 2H, ArH), 7.28-7.35 (m, 5H, ArH), 7.39-7.42 (m, 2H, ArH), 7.67 (dd, *J* 7.2, 1.6 Hz, 1H, ArH), 8.03 (dd, *J* 8.5, 1.1 Hz, 2H, ArH) 8.52 (dd, *J* 7.5, 1.5 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm)104.1, 114.5, 124.0, 124.9, 126.1, 126.7,

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128.2, 128.2, 128.2, 128.3, 129.8, 130.2, 132.5, 133.6, 133.8, 151.4, 154.1; IR(cm^{-1}): 1475, 1257; LCMS (ESI):Calculated for $C_{21}H_{14}N_2SSe$ $[M]^+$ 406.00, found $[M+1]^+$ 407.08.

3-(Phenylselanyl)-2-(*p*-tolyl)benzo[*d*]imidazo[2,1-*b*]thiazole (2q). White solid (256.2 mg, 81% yield), mp 123-125 °C; ^1H NMR (500 MHz, $CDCl_3$) δ (ppm) 2.38 (s, 3H, CH_3), 7.17-7.24 (m, 1H, ArH), 7.24-7.30 (m, 4H, ArH), 7.30-7.33 (m, 2H, ArH), 7.33-7.36 (m, 2H, ArH), 7.70 (dd, *J* 7.3, 1.8 Hz, 1H, ArH), 7.91 (d, *J* 8.1 Hz, 2H, ArH) 8.54 (dd, *J* 7.1, 2.2 Hz, 1H, ArH); ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm): 21.3, 103.7, 114.5, 124.0 ,124.8, 126.1, 126.1,126.6, 128.1, 129.0, 129.8, 130.2, 130.6, 132.5, 133.8, 138.1, 151.6, 154.3; IR(cm^{-1}): 1476, 1326; LCMS (ESI):Calculated for $C_{22}H_{16}N_2SSe$ $[M]^+$ 420.01, found $[M+1]^+$ 421.02.

2-(4-Methoxyphenyl)-3-(phenylselanyl)benzo[*d*]imidazo[2,1-*b*]thiazole (2r). White solid (243.6 mg, 81% yield), mp 120-124 °C; ^1H NMR (500 MHz, $CDCl_3$ δ (ppm) 3.83 (s, 3H, OCH_3), 6.95 (dd, *J* 9.7, 2.0 Hz, 2H, ArH), 7.16-7.19 (m, 1H, ArH), 7.20-7.23 (m, 2H, ArH), 7.25-7.27(m, 2H, ArH), 7.29-7.35 (m, 2H, ArH), 7.69 (dd, *J* 7.4, 1.6 Hz, 1H, ArH), 7.98 (dd, *J* 6.8, 2.0 Hz, 2H, ArH), 8.53(dd, *J* =7.2, 1.5 Hz, 1H, ArH). ; ^{13}C NMR (125 MHz, *C*DCl_3) δ (ppm) 55.2, 103.1, 113.7, 114.4, 123.9, 124.8, 126.1, 126.2, 126.6, 128.1, 129.5, 129.8, 130.1, 132.6, 133.8, 151.3, 154.1, 159.6; IR (cm^{-1}): 1474, 1257; LCMS (ESI):Calculated for $C_{22}H_{16}N_2OSSe$ $[M]^+$ 436.01, found $[M+1]^+$ 437.04 .

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Supplementary Material

Copies of ^1H and ^{13}C NMR spectra of compounds **2a**-**2r** (18 compounds) are given in the Supplementary Material file associated with this manuscript.

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